

ENERGY DEPOSITION STUDIES FOR OPEN-MIDPLANE LARP DIPOLES

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Review of LARP Separation Dipole R&D

BNL

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OUTLINE

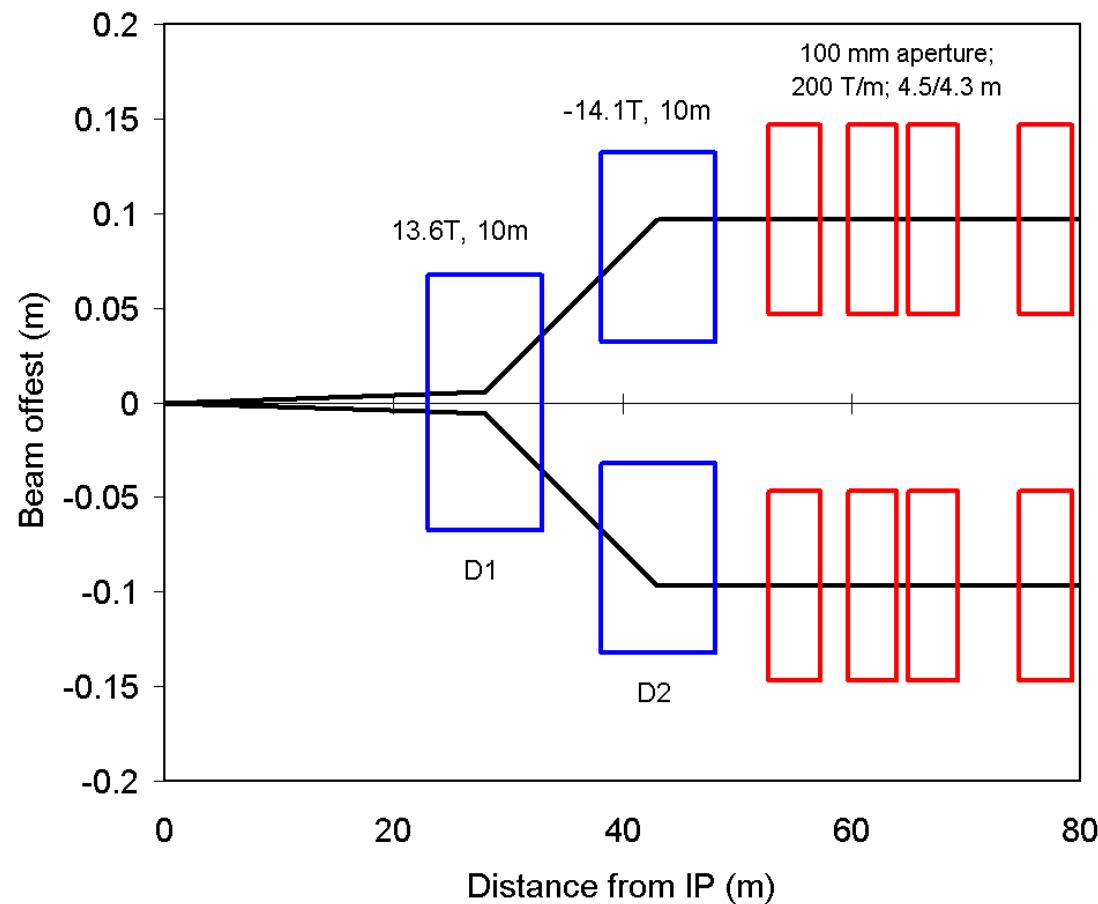
- Introduction
- Energy Deposition Constraints
- Dipole Designs and First Results (version 1)
- 2004 Results for the Open Midplane Dipole (version 2)
- Towards a Compact Design (version 3)
- Summary

INTRODUCTION

The LHC interaction region (IR) was designed to achieve a nominal luminosity of $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with the lifetime of low- β quadrupoles limited by radiation loads to 6-7 years. After that, it is planned to replace the low- β insertions with a higher performance design based on advanced superconducting magnets to upgrade a luminosity up to $10^{35} \text{ cm}^{-2}\text{s}^{-1}$. Preliminary studies show that, with magnet technology that is expected to be developed by early in the next decade, a factor of 2 to 5 reduction in β^* could be achieved with new insertions.

Three major factors drive the designs of new IRs: minimizing β^* , minimizing the effects of long-range parasitic beam-beam interactions, and the large radiation loads due to pp-collisions (9 kW/beam at $10^{35} \text{ cm}^{-2}\text{s}^{-1}$) directed towards the IRs. The first two point towards maximizing the magnet apertures and minimizing their distances to the IP. Here I will summarize results of our energy deposition studies for the LARP open-midplane dipole IRs.

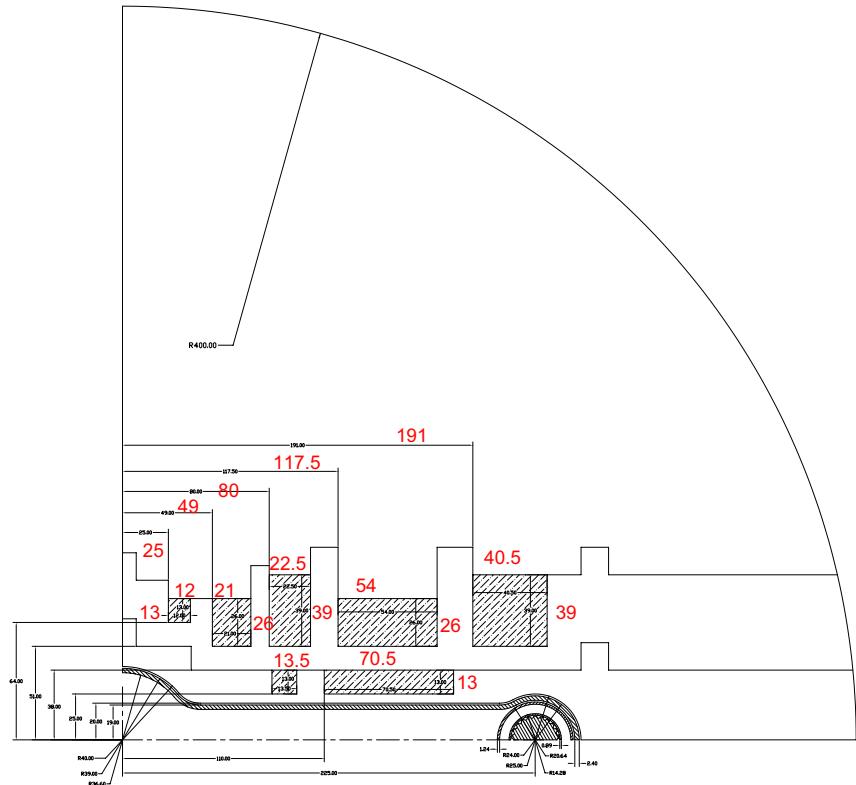
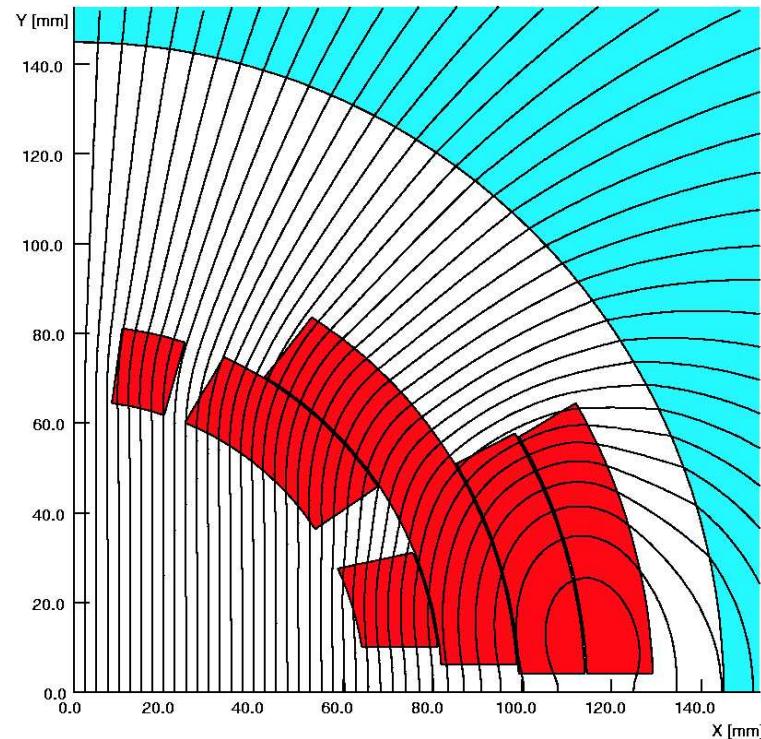
DIPOLE-FIRST IR LAYOUT



ENERGY DEPOSITION ISSUES

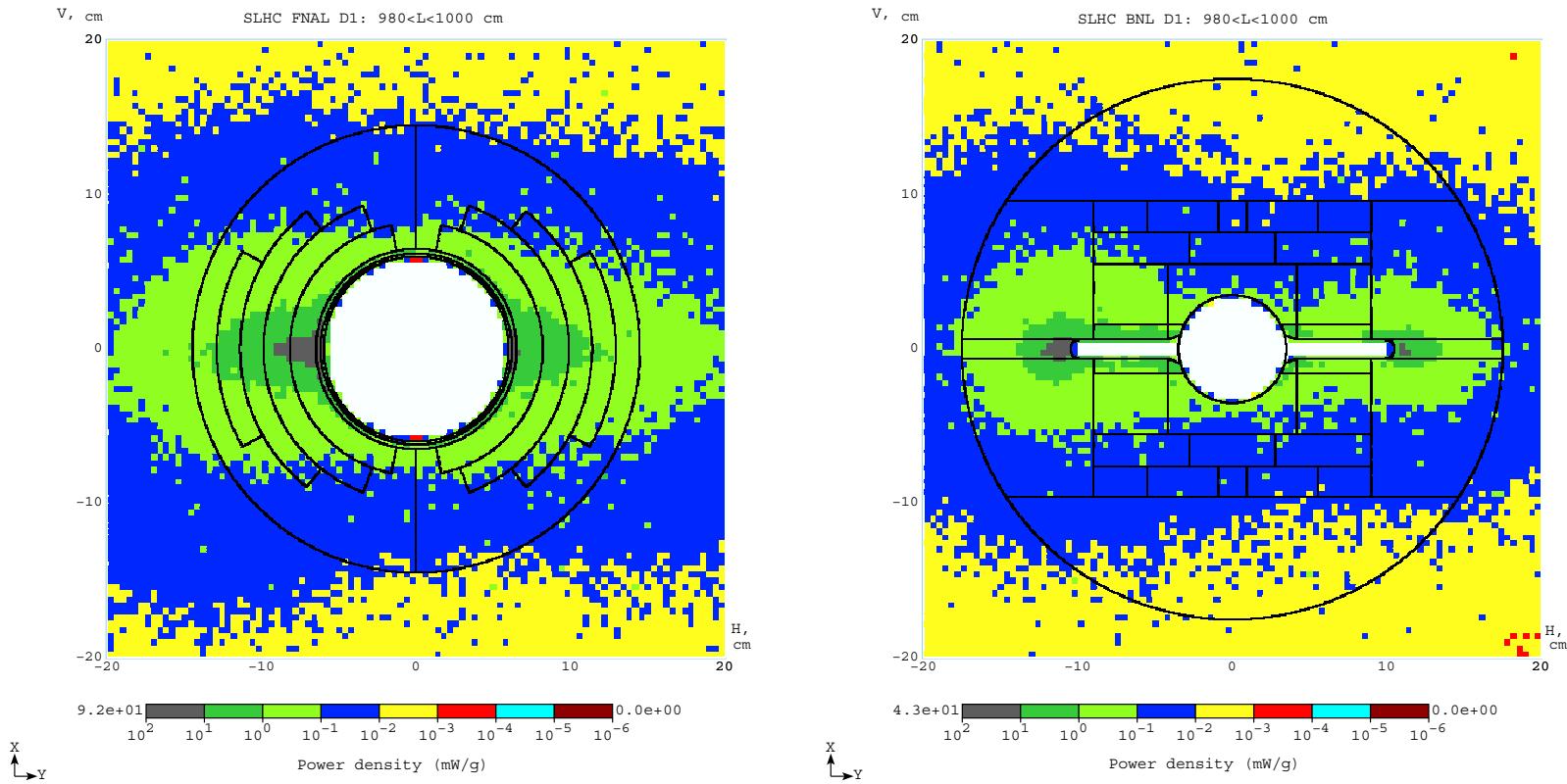
1. Quench stability: peak power density in SC coils and heat transfer.
2. Dynamic heat loads: Power dissipation and cryogenic implications.
3. Residual dose rates: hands-on maintenance.
4. Components lifetime: peak radiation dose in components and limits for various materials.

DIPOLE-FIRST MAGNET DESIGNS



Peak power density is a factor of 100 higher in LARP dipole ($\mathcal{L} = 10^{35}$) than in LHC IR quads ($\mathcal{L} = 10^{34}$).

DIPOLE-FIRST: FIRST RESULTS (2003)

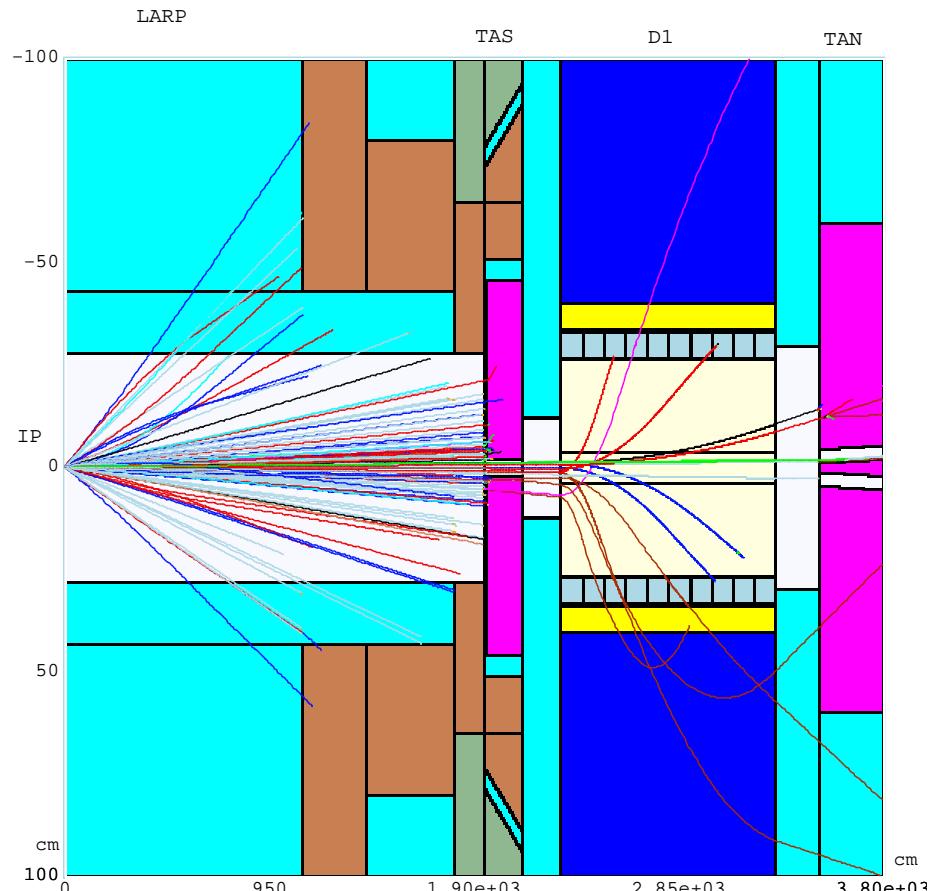


Peak power density is 49 mW/g in copper spacer and 13 mW/g in SC coil (left) and only 1.1 mW/g in the SC coils of block-type dipole-v1 (right). Total power dissipated in the dipole is 3.5 kW in either design.

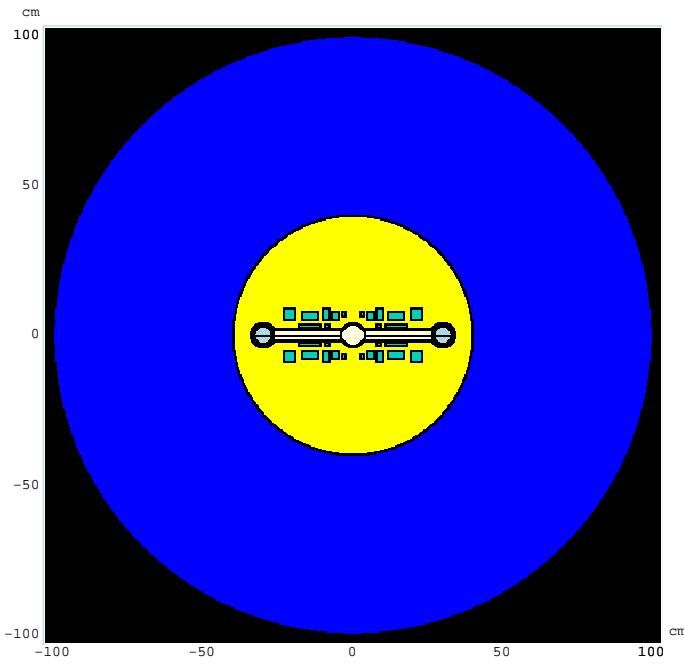
LARP ENERGY DEPOSITION STUDIES IN 2004

1. MARS15 code developments: improved hadron-nucleus x-sections, forward low- p_t physics (inelastic, diffractive, elastic, correlated Coulomb scattering and energy loss), heavy-ion modules, advanced MAD-MARS Beam Line Builder (MMBLB), multiprocessing version, histograming in tiny structures, DPA modeling, advanced residual dose modeling.
2. Building and iterating on MARS model of the Open Midplane Dipole (**v1 → v2**).
3. Realistic MARS modeling of the dipole-first (**v2**) IRs addressing four energy deposition issues: quench stability, dynamic heat load, DPA and residual dose.
4. Move to a compact design (**v2 → v3**), first MARS15 results of December 12, 2004.

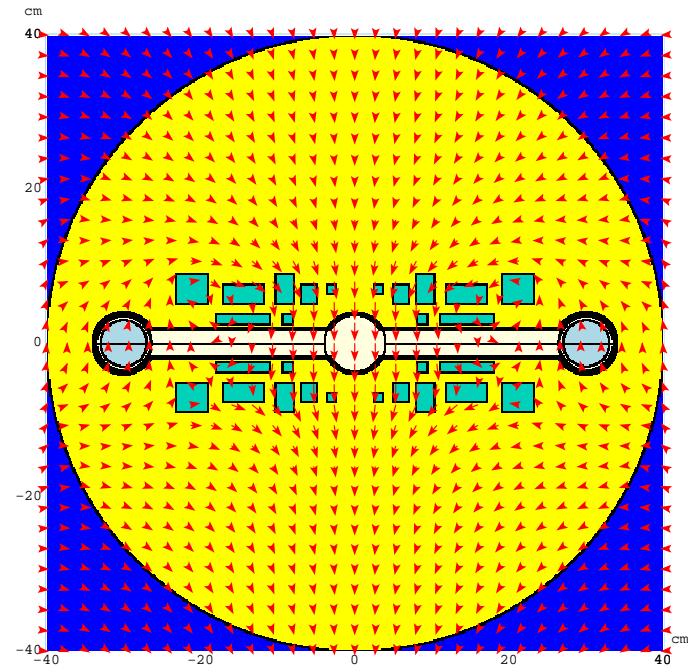
DIPOLE-FIRST IR: ONE PP-EVENT



OPEN-MIDPLANE MARS MODEL (V2)

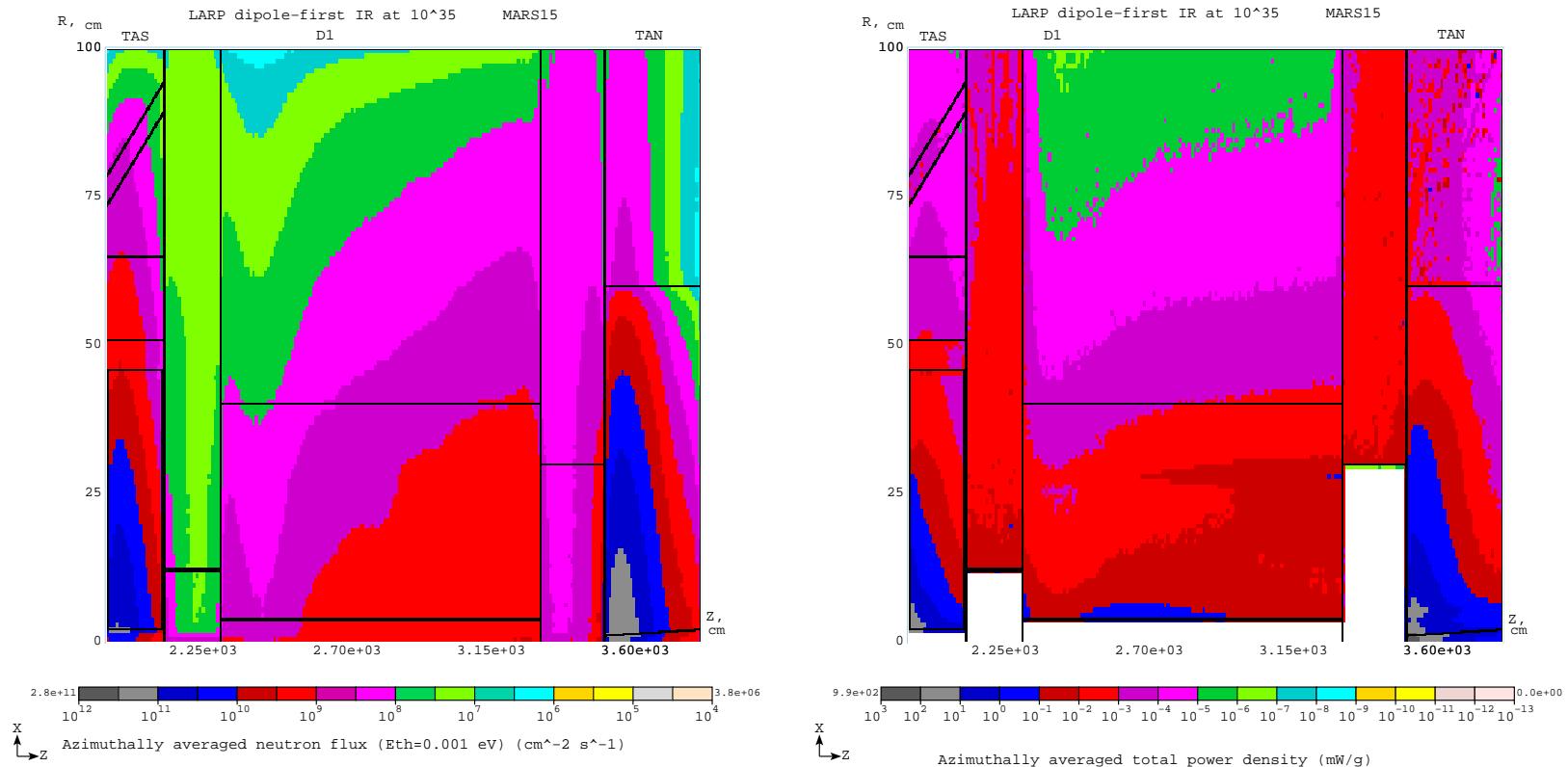


X
Y

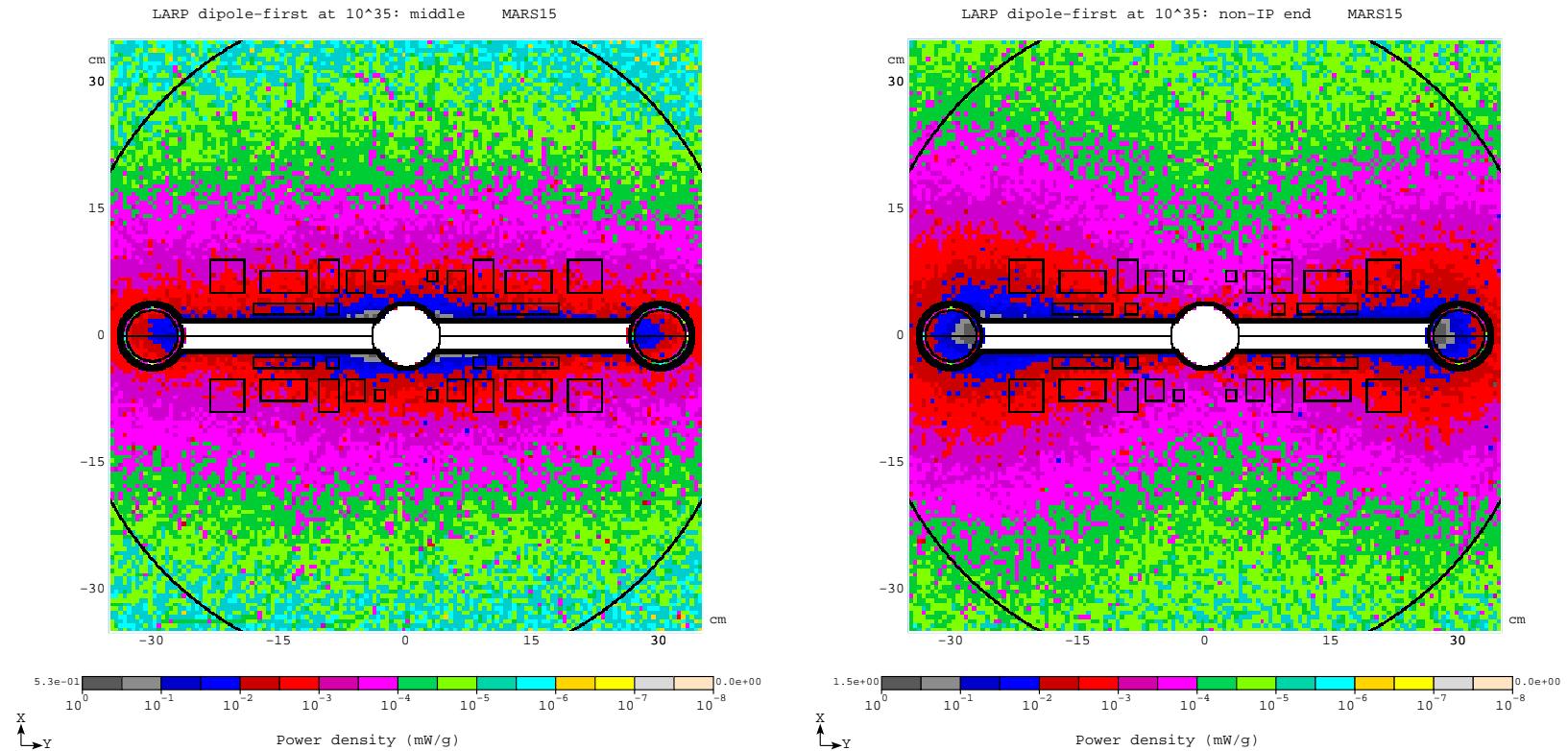


X
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FLUX AND POWER DENSITY LONGITUDINAL PROFILES (V2)



POWER DENSITY AT TWO LONGITUDINAL MAXIMA (V2)



Peak power density in SC coils ≤ 0.01 mW/g, well below the quench limit.

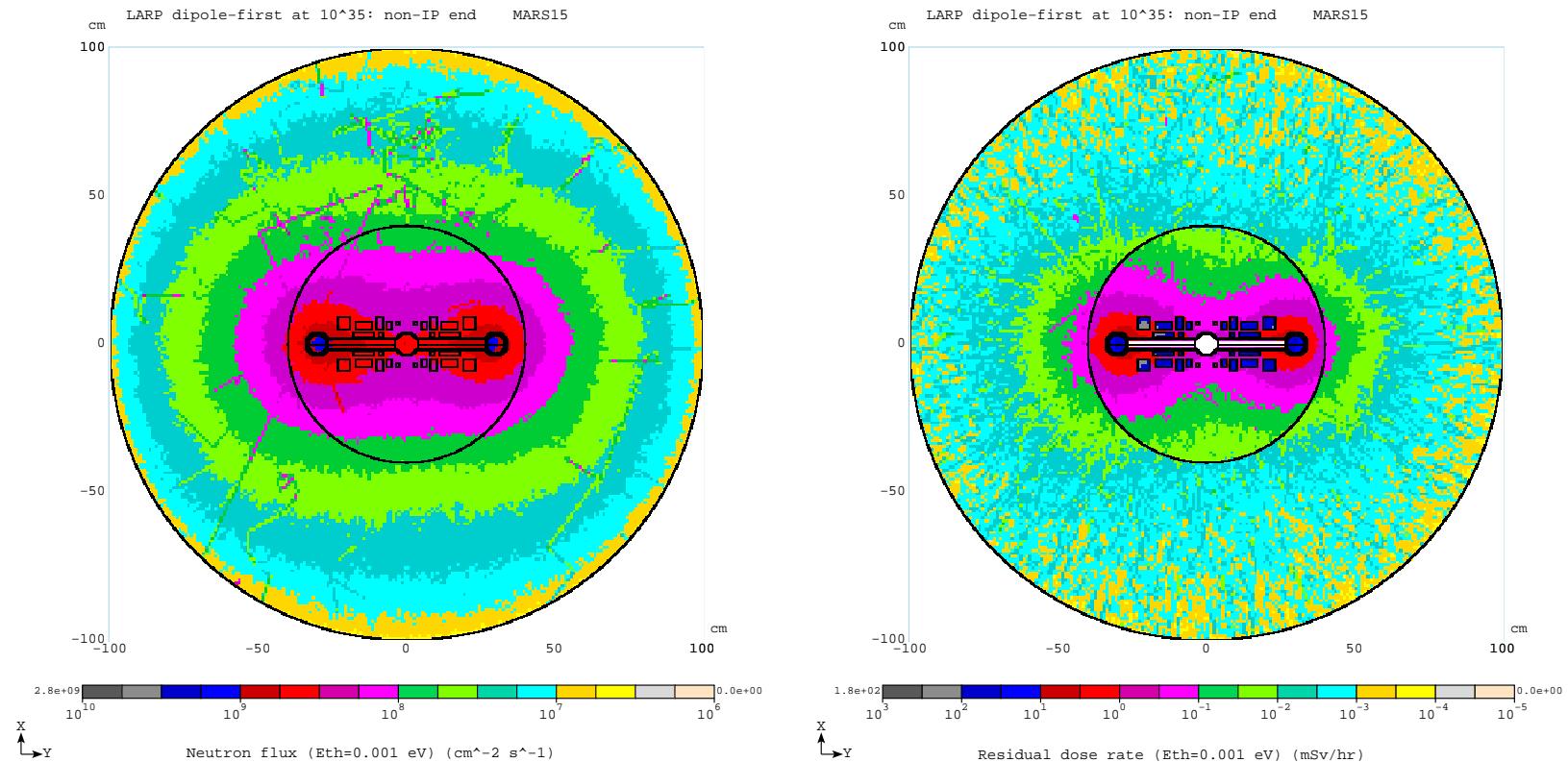
DYNAMIC HEAT LOAD TO DIPOLE CRYO (V2)

Component	Power Dissipation (W)
SC coils	30.4
Beam pipe	49.3
W-rod	235
Rod vessel	5.0
Collar	184
Yoke	14.1
TAS	1750
Downstream	5315

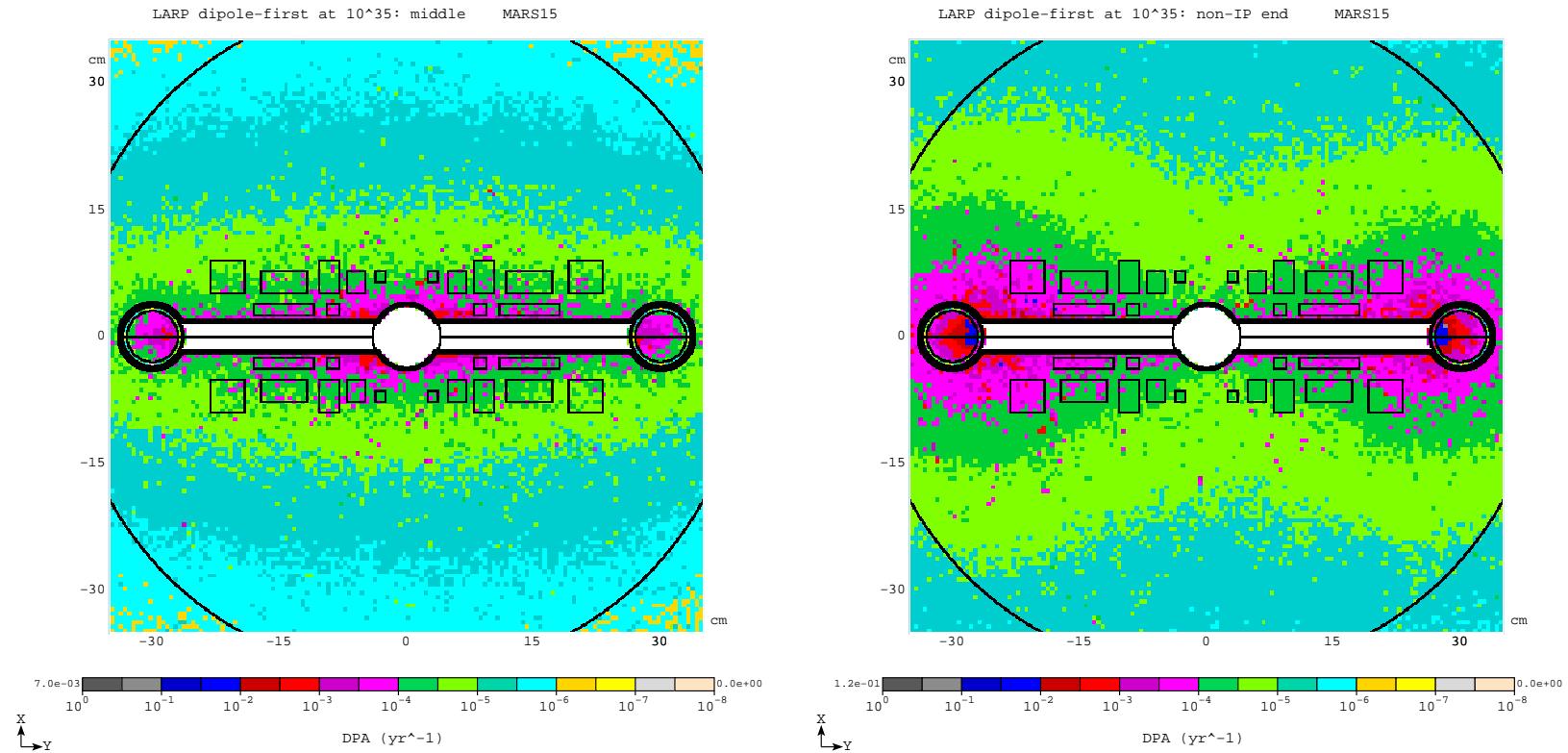
Heat loads to seven coils: 1.6, 6.7, 0.3, 1.2, 1.5, 2.5, 2.8 Watts.

Longitudinal distribution of heat load to the coils is rather uniform: 3 W/m.

NEUTRON FLUX AND RESIDUAL DOSE (V2)

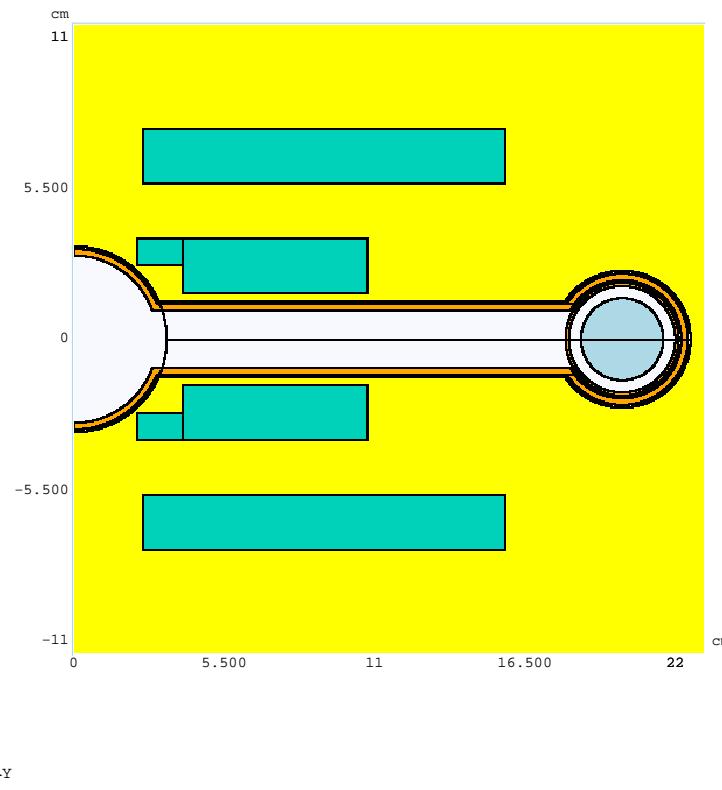
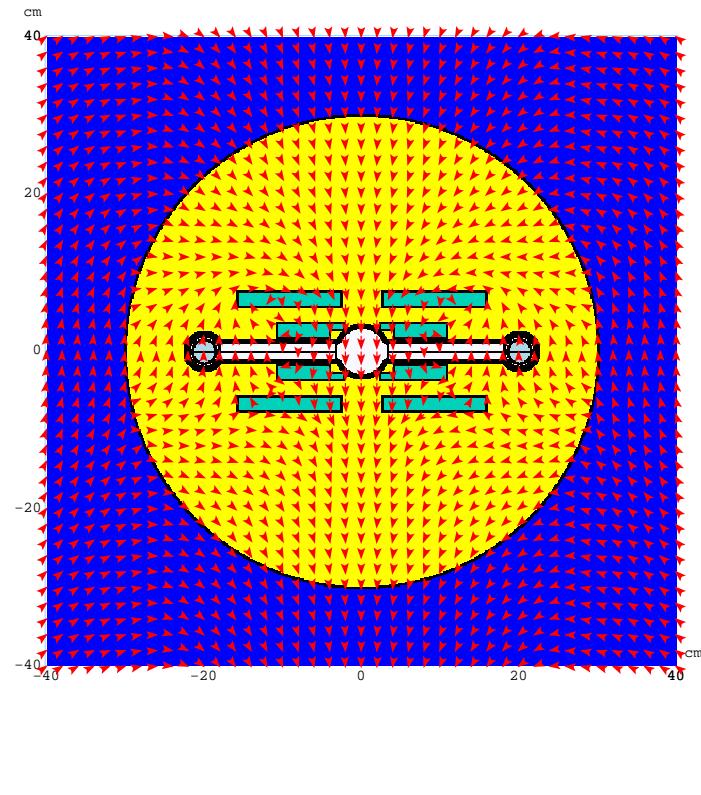


DPA AND COMPONENT LIFETIME (V2)



Peak DPA rate in SC coils is below 0.01 DPA/yr that corresponds to a lifetime of tens of years.

OPEN-MIDPLANE MARS MODEL (V3) DEC. 2004

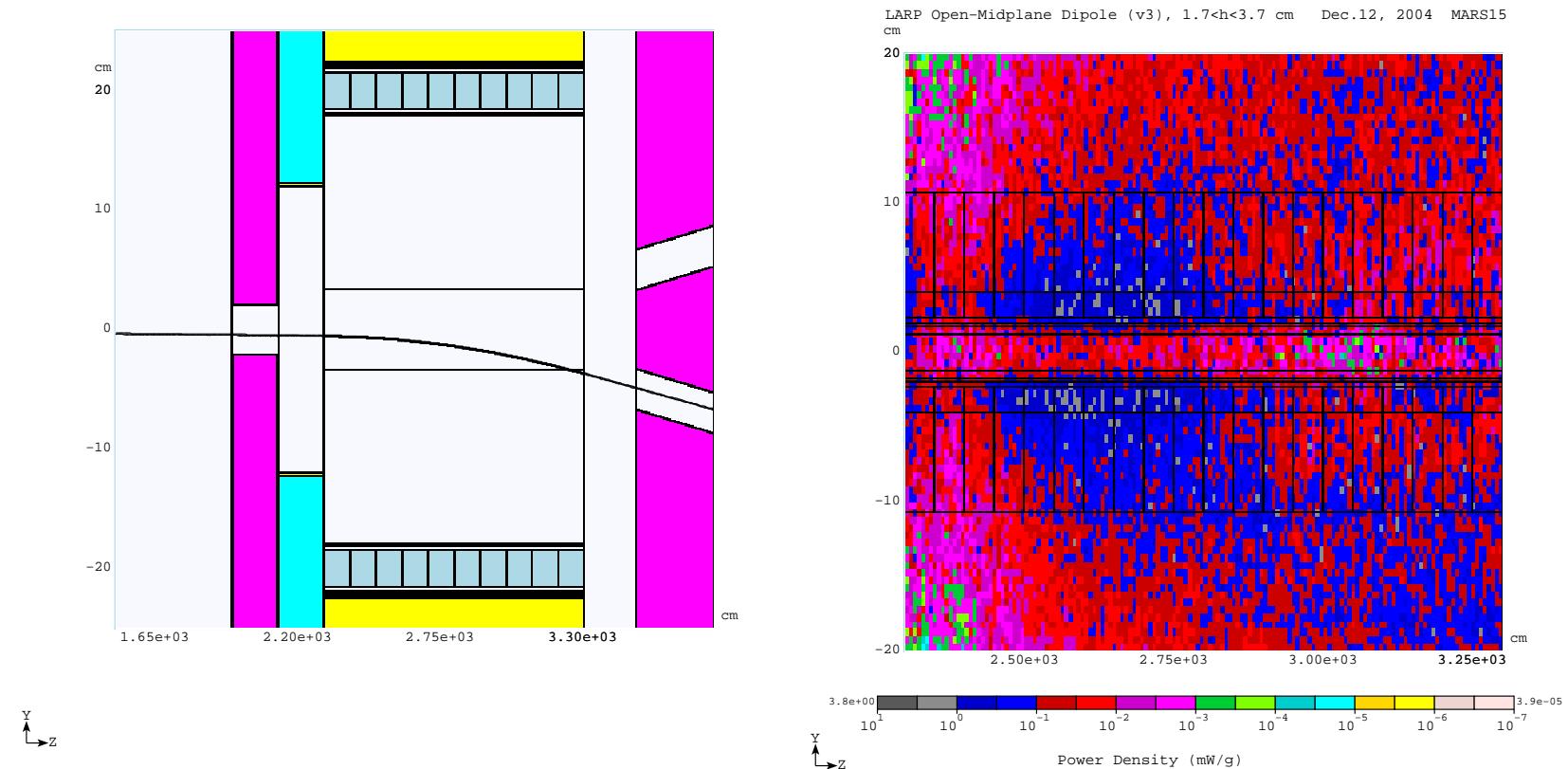


PARAMETERS CRITICAL TO ENERGY DEPOSITION:

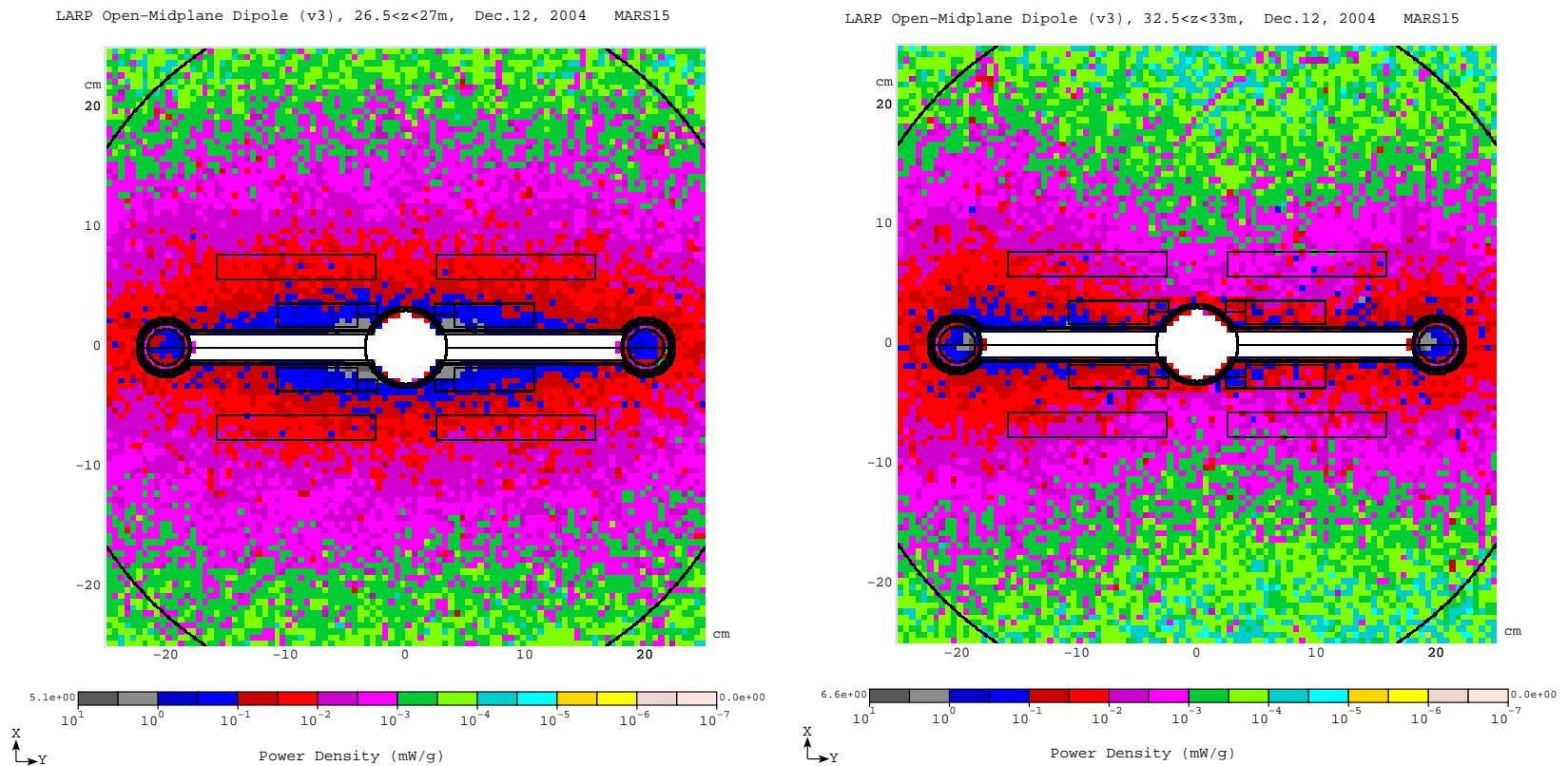
V2 → V3

Parameter	V2	V3
Distance to the closest SC coil (vert/hor)	25/80	17/40
Open midplane half-width (rod location)	300	200
Space between midplane and collar	20	14
Open midplane half-height	16.6	10.6
Radius of central hole in collar	40	34
Radius of central aperture	36.6	30.6
Radius of tungsten rod	30	15
Yoke inner/outer radii	400/1000	300/700

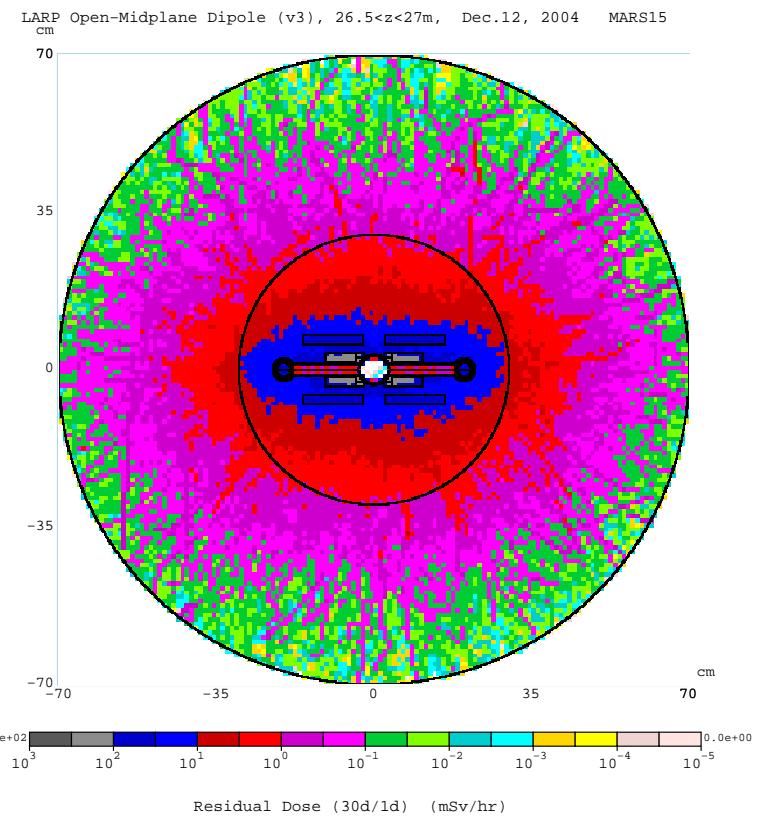
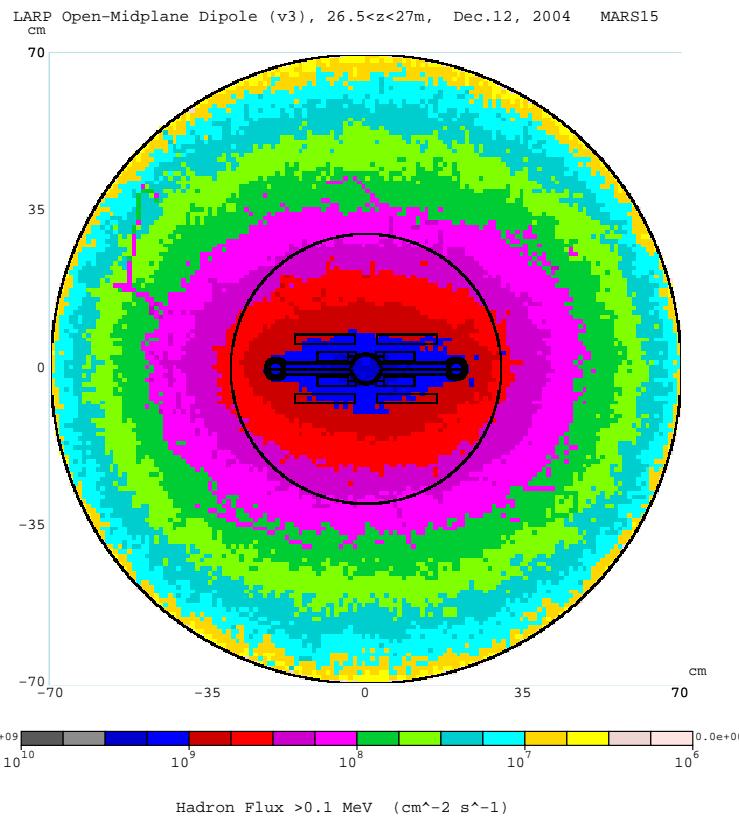
OPEN-MIDPLANE DIPOLE (V3) DEC. 2004



POWER DENSITY AT TWO LONGITUDINAL MAXIMA (V3)



HADRON FLUX AND RESIDUAL DOSE (V3)



SUMMARY

- The 2004 versions of the open midplane dipole design are very attractive for the LARP dipole-first IR at $\mathcal{L} = 10^{35}$. The design accommodates large vertical forces, has desired field quality of 10^{-4} along the beam path and is technology independent.
- The “large” design (V2) has a significant margin from energy deposition standpoint: peak power density in SC coils is well below the quench limit; about a half of dynamic heat load is dissipated in tungsten rods and can be removed at nitrogen temperature; residual dose rates on the outside of the dipole are below the limits; DPA rates in SC coils and rod cryostat correspond to ≥ 20 years of lifetime.
- The “compact” design (V3), moving in the right direction, is not adequate yet for the luminosity of $\mathcal{L} = 10^{35}$. First results of MARS15 modeling show that the energy deposition limits are exceeded. Further work is needed to satisfy energy deposition constraints and provide corresponding safety margins.